

Calorimeter Assisted Tracking Algorithm for SiD

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Calorimeter-assisted track finding algorithm takes advantage of the finely segmented electromagnetic calorimeter proposed for the SiD detector concept by looking for "MIP stubs" produced by charged particles in the calorimeter, and using them as seeds for pattern recognition in the tracker. The algorithm allows for efficient reconstruction of tracks that cannot be found using seeds provided by the vertex detector, even if standalone pattern recognition in the outer tracker is difficult. The algorithm has been implemented as a package in the org.lcsim framework. Current status of the package and its performance in non-prompt tracks reconstruction are described.

1 Introduction

The development of the calorimeter assisted tracking algorithm was originally motivated by the need to reconstruct long-lived particles in the SiD detector [2].

To minimize multiple scattering and energy loss in the central tracker while providing excellent vertex finding capabilities and high precision measurement of the charged tracks momenta, the SiD baseline design utilizes a compact five-layer silicon pixel vertex detector and a five-layer silicon strip outer tracker, possibly with no stereo and limited Z-segmentation in the barrel.

The standard track finding algorithm developed for the SiD relies on identifying tracks in the vertex detector, where pattern recognition is simplified by the fact that precise three-dimensional information is available for each hit. The tracks are then propagated into the outer tracker, additional hits are picked up, and the track curvature is measured. This algorithm has been demonstrated [3] to achieve high efficiency in reconstructing most types of tracks. However, its heavy reliance on seeds provided by the vertex detector raises a number of questions that need to be addressed. One obvious issue is that the tracks that originate outside the third layer of the vertex detector cannot be reconstructed using this approach, since they do not leave enough hits in pixels to generate a seed. Decay products of K_S^0 and Λ are important examples of particles producing such non-prompt tracks. The detector should also be capable of detecting new physics signatures that would include long-lived exotic particles like those predicted by some gauge-mediated supersymmetry breaking scenarios.

In order to address this issue, a track finding algorithm has been developed that uses electromagnetic calorimeter to provide seeds for pattern recognition in the tracker. Fine segmentation of the EM calorimeter allows for detection of traces left by minimum ionizing particles - so called MIP stubs - and using them to determine the track entry point, direction, and sometimes curvature with a precision sufficient for extrapolating the track back into the tracker.

2 Algorithm

With calorimeter assisted tracking, track finding goes through the following main steps:

1. The standard vertex detector seeded track finder is run. Tracker hits that are associated with successfully reconstructed tracks are removed.
2. MIP stubs in the electromagnetic calorimeter are identified. Several alternative algorithms can be used at this step, such as a generic nearest-neighbor clustering followed by user-controlled cluster quality cuts, or a dedicated MIP stub finder developed specifically for the SiD geometry. For each MIP stub, a seed track is created, and initial helix parameters are determined.
3. Seed tracks are extrapolated back into the tracker, picking up hits in each layer. Every time a hit is added to the track, the track is re-fitted to get a more precise estimate of its parameters. If multiple hit candidates are found in a given layer, the track finding process is branched and several independent track candidates are created.
4. Quality cuts are applied to track candidates; duplicate tracks that share too many hits are discarded.
5. Vertex finder is run; if track intersections are found, the original particles that produced these secondary vertices are reconstructed.

The algorithm has been implemented as a package (`org.lcsim.recon.cat`) in the Java based `org.lcsim` framework [4]. The package design is highly modular, allowing easy substitution of components implementing different algorithms at various stages of the event processing. Most of the track finder parameters can be set at run time, making it possible for the user to tune the algorithm and use it as a part of more complex reconstruction strategies that can involve multiple track finders and multiple passes through the data.

The code can be run both standalone and inside JAS3 interactive shell [5]. The implementation is largely decoupled from any particular geometry, which allows the algorithm to be used for studying and optimizing a wide range of SiD detector options, as well as other ILC detectors designs.

3 Performance

The package was tested by reconstructing simulated events in the SiD detector. For this study, the "SiD00" version of the detector design was used. Since proper charge deposition and digitization code was not yet available, point-like hits produced by the simulation software were smeared with the expected position resolution. In the outer tracker barrel, no stereo layers and 10 cm silicon strips parallel to the beam line were modeled. Strips on opposite sides of the endcap disks were assumed to be perpendicular to each other, forming 90 degrees stereo superlayers, with 10 cm strip length.

Figure 1 shows reconstruction efficiency obtained with the calorimeter assisted tracking algorithm for charged π mesons produced in single K_S^0 events, as a function of transverse momentum. Pions are considered reconstructable if they leave hits in at least 3 tracker layers. Figure 2 shows reconstruction efficiency for K_S^0 in the same type of events. Hollow points refer to the actual efficiency obtained with the current version of the package. Since

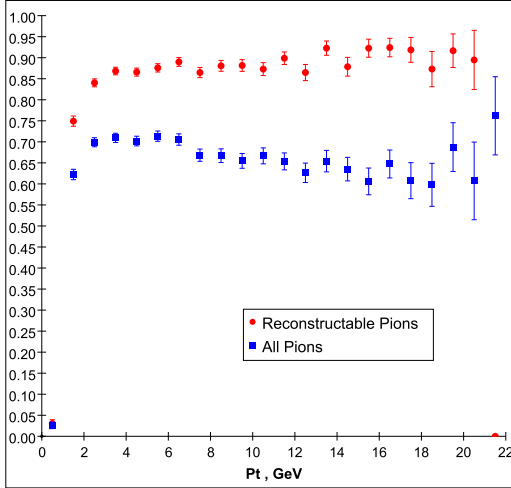


Figure 1: Reconstruction efficiency for charged π mesons from K_S^0 decays in single K_S^0 events, as a function of transverse momentum.

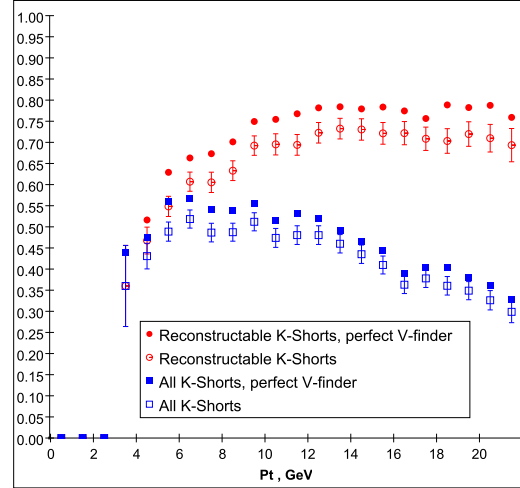


Figure 2: K_S^0 reconstruction efficiency as a function of transverse momentum. Single K_S^0 events.

the currently used vertex finder is a simplistic tool expected to be replaced by a more advanced algorithm once the latter is ported to the org.lcsim framework, the efficiency that would be obtained with a perfect vertex finder is also shown (filled points). K_S^0 is considered reconstructable if it decays in the sensitive area of the detector (inside the third layer of the outer tracker).

Figure 3 shows K_S^0 reconstruction efficiency in $t\bar{t}$ events at 500 GeV center-of-mass energy. For comparison, less than 3 % of all K_S^0 produced in such events would have been reconstructed by the vertex detector seeded algorithm. Figure 4 shows reconstructed K_S^0 mass peak in $t\bar{t}$ events.

4 Discussion

The calorimeter assisted tracking algorithm addresses one of the critical issues for the proposed SiD detector - reconstruction of long lived particles. It can also be instrumental in reconstructing kinked tracks that lose a substantial portion of their energy in the tracker, as well as calorimeter backscatters. Availability of this algorithm significantly improves overall robustness of the track reconstruction in SiD, reducing its reliance on the vertex detector.

The performance tests described in the previous section have been carried out using the current version of the algorithm implementation. Several enhancements are already in the works, and we expect substantial performance improvements.

One of the areas where improvements are desirable is reconstruction of low momentum tracks. As seen in Figure 1, the reconstruction efficiency falls sharply for charged pions with transverse momenta below 1 GeV. Many of these tracks never reach the calorimeter barrel and, after leaving many hits in the tracker, enter calorimeter endcaps at shallow angles, making accurate determination of track parameters from MIP stubs difficult. Our

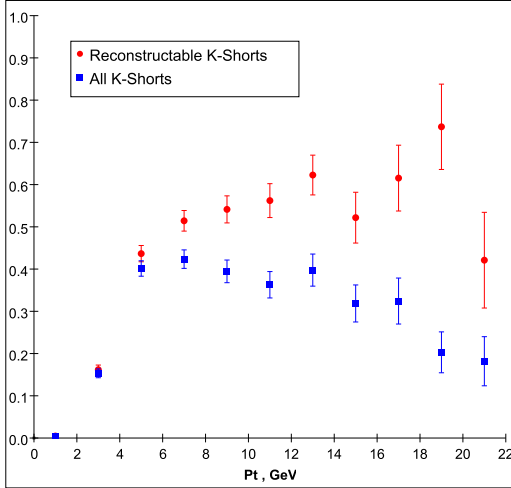


Figure 3: K_S^0 reconstruction efficiency as a function of transverse momentum. 500 GeV $t\bar{t}$ events.

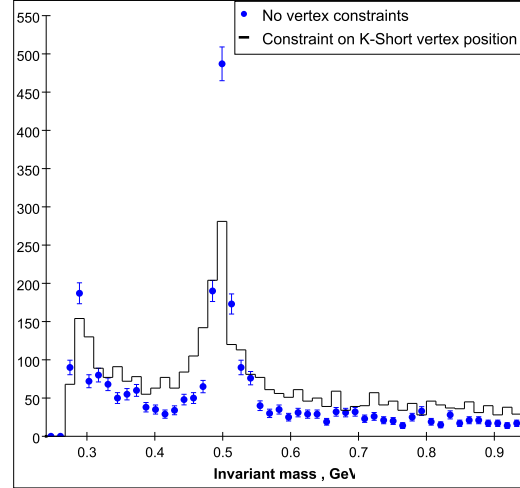


Figure 4: Reconstructed $\pi^+\pi^-$ mass. 500 GeV $t\bar{t}$ events.

preliminary studies indicate, however, that more flexible fitting and track extrapolation procedures may let us recover a substantial portion of these tracks. We expect to implement these procedures once the infrastructure required to support them becomes available in the org.lcsim framework.

The package implementing the calorimeter assisted tracking algorithm will remain under continuing development in the near future. However, a fully functional version will be maintained in the org.lcsim production area. It will be used for SiD geometry optimization and physics reach studies.

References

- [1] Slides:
<http://ilcagenda.linearcollider.org/contributionDisplay.py?contribId=312&sessionId=74&confId=1296>
- [2] SiD Detector Concept:
<http://www-sid.slac.stanford.edu/>
- [3] N. B. Sinev, *In the Proceedings of 2005 International Linear Collider Workshop (LCWS 2005), Stanford, California, 18-22 Mar 2005, pp 1009.*
- [4] org.lcsim framework:
<http://www.lcsim.org/software/lcsim/index.html>
- [5] T. Johnson, *In the Proceedings of CHEP'01: Computing in, High-Energy Physics and Nuclear, Beijing, China, 3-7 Sep 2001*